



IMAAC

**Interagency Modeling and
Atmospheric Assessment Center**

REAL WORLD

Possible Sulfur Dioxide Release and Ongoing Organic Peroxide Fires at Arkema Chemical Plant in Crosby, Texas

RFI – 17 – 0831U Update #8: Weather, removed all southern tanks of organic peroxide

02SEP2017

Requestor: EPA Region 6

02SEP2017 1500Z

Distribution authorized to U.S. Government agencies and
their contractors for administrative/operational use.

Date: 02 SEP 2017

Other requests for this document shall be referred to:

Defense Threat Reduction Agency

8725 John J. Kingman Rd, MS 6201

Fort Belvoir, VA 22060-6201



Request Summary

• (U//FOUO) Request Data

- Requestor: Larisa Leonova, EPA Region 6
- Contact: 202-578-3043, Leonova.Larisa@epa.gov
- Request: Downwind hazard analysis of the possible release of sulfur dioxide and the effects of an organic peroxide fire and possible isobutylene BLEVE at a chemical plant in Crosby, TX.

• (U//FOUO) Solution

- Summary: Acute Exposure Guideline Levels (AEGL), soot concentration and blast circles provided.
- Employment: Real World
- Reachback: Reachback Team

Location: Arkema Chemical Plant,
Crosby, Texas
Average Location of All Containers:
Latitude: 29.9491° N
Longitude: 95.0211° W

Date/Time:
2000Z 02SEP2017 – 2000Z 03SEP2017

Hazard:

- Sulfur dioxide (~32,000 lbs)
- Organic peroxide fire
 - 6 containers 38,000 lbs each
- Isobutylene (38,000 lbs)

Weather:

- High Resolution Numerical Weather Prediction: 3 km NAM from NCEP (CONUS)



Modeling Summary

- Known Information: Generators at the Arkema Chemical Plant, Crosby, Texas are not able to provide cooling to stored chemicals as a consequence of Hurricane Harvey. The facility contains Chlorine (~ 300 lb), sulfur dioxide (~32,000 lb), Organic Peroxide (~ 0.25 million lb), and 38,000 lb isobutylene.
- Modeling Assumptions:
 1. Sulfur dioxide modeled as a stuck open relief valve.
 2. Fire/explosion of a single or multiple containers of organic peroxides, 38,000 lb of peroxide per container. Organic peroxides can spontaneously detonate if not kept cool.
 - Peroxide fire modeled as benzoyl peroxide, a confined pool fire of approximately one hour and more lofting due to oxygenates.
 3. Isobutylene BLEVE (boiling liquid expanding vapor explosion) was modeled using TNT equivalents. For this to occur, the tank would have to be leaking and extremely hot.



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Location Overview – Near View





SO₂ (Release Starting @ 02 SEP 3:00 PM CDT) – Update #8

Note: AEGL values for SO₂ may overestimate effects.

* Arkema Chemical Facility
1.5 mile Radius

Sulfur Dioxide(AEGLs)
03-Sep-17 00:00:00Z (4.000 hr)

Mean Area

	Value
AEGL-3 Death Possible	3.0
AEGL-2 Injury Possible	2.0
AEGL-1 not displayed	

FACTS

Crosby, Texas

Location: 29.9491° N/ 95.0211° W

Event Time: 3:00 PM CDT, 02SEP2017

Type: Sulfur Dioxide

Amount: 32,000 lb (16,000 lbs/hr)

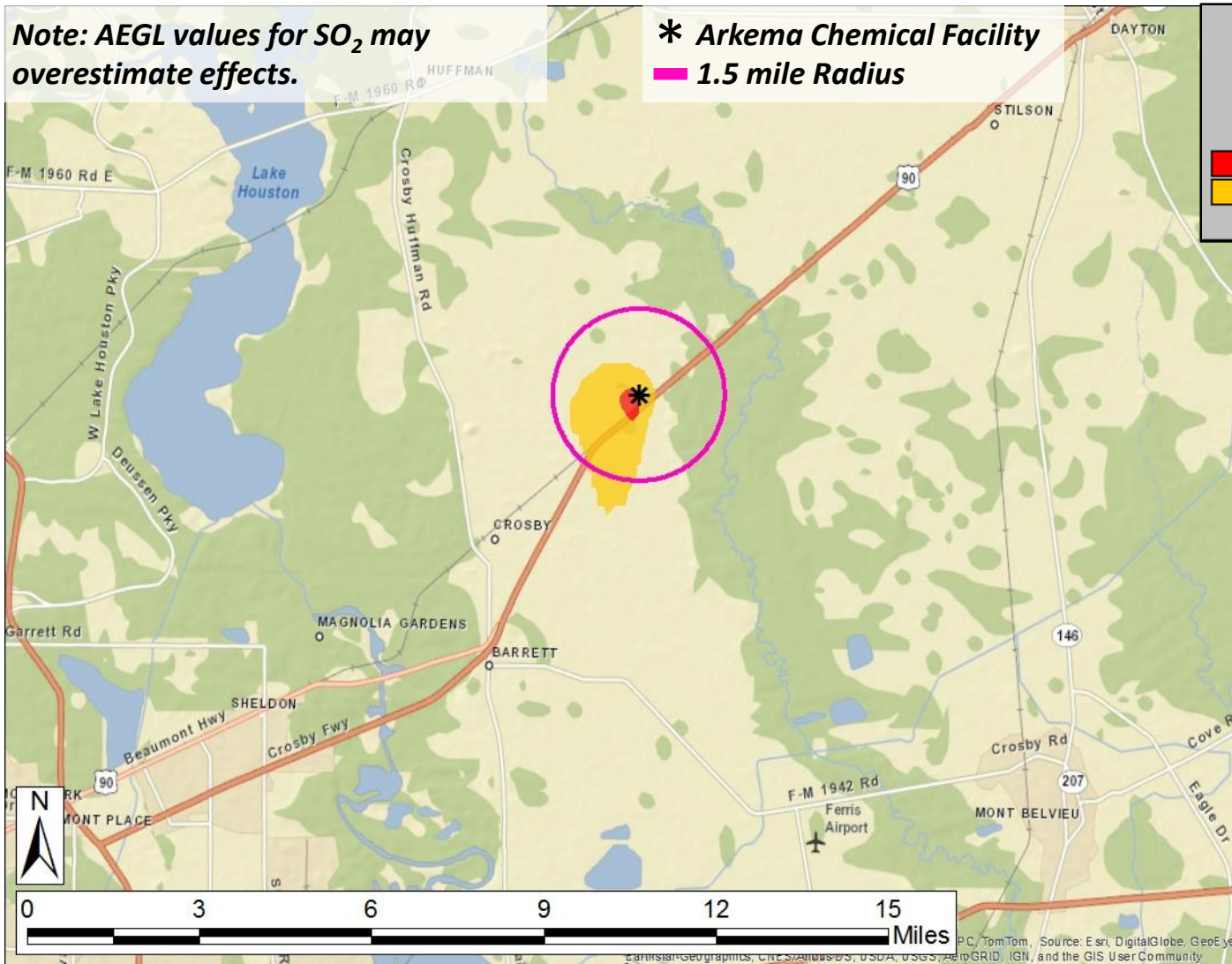
Dissemination: Release over 2 hours

Weather: 3 km NAM

Model: HPAC 6.4

Static Population Estimates:

LandScan 2015



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNR/Spanner, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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SO₂ (Release Starting @ 02 SEP 9:00 PM CDT) – Update #8

Note: AEGL values for SO₂ may overestimate effects.

* Arkema Chemical Facility
1.5 mile Radius

Sulfur Dioxide(AEGLs)
03-Sep-17 06:00:00Z (4.000 hr)

Mean Area

	Value
AEGL-3 Death Possible	3.0
AEGL-2 Injury Possible	2.0
AEGL-1 not displayed	

FACTS

Crosby, Texas

Location: 29.9491° N/ 95.0211° W

Event Time: 9:00 PM CDT, 02SEP2017

Type: Sulfur Dioxide

Amount: 32,000 lb (16,000 lbs/hr)

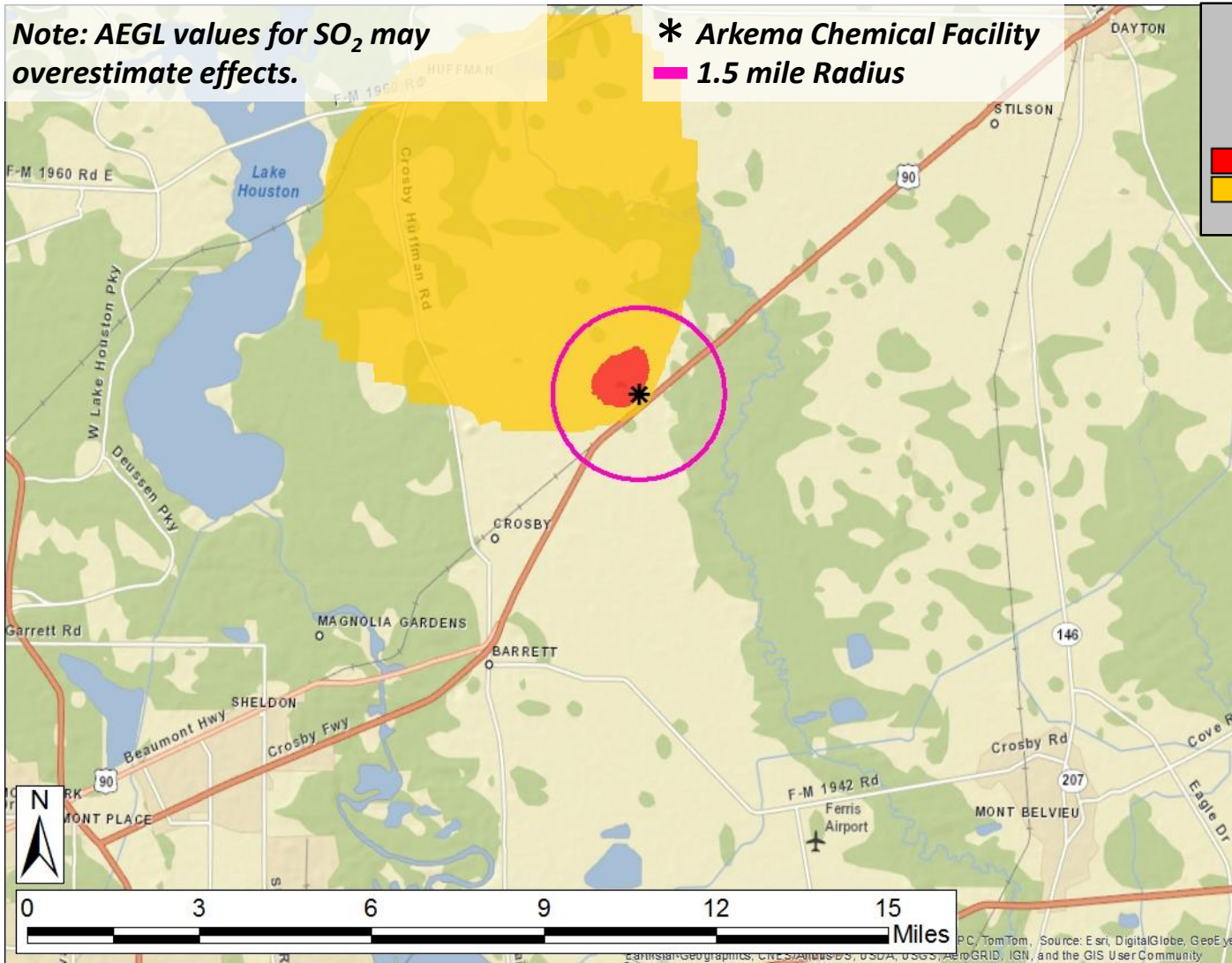
Dissemination: Release over 2 hours

Weather: 3 km NAM

Model: HPAC 6.4

Static Population Estimates:

LandScan 2015





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SO₂ (Release Starting @ 03 SEP 3:00 AM CDT) – Update #8

Note: AEGL values for SO₂ may overestimate effects.

* Arkema Chemical Facility
1.5 mile Radius

Sulfur Dioxide(AEGLs)
03-Sep-17 12:00:00Z (4.000 hr)

Mean Area

	Value
AEGL-3 Death Possible	3.0
AEGL-2 Injury Possible	2.0
AEGL-1 not displayed	

FACTS

Crosby, Texas

Location: 29.9491° N/ 95.0211° W

Event Time: 3:00 AM CDT, 03SEP2017

Type: Sulfur Dioxide

Amount: 32,000 lb (16,000 lbs/hr)

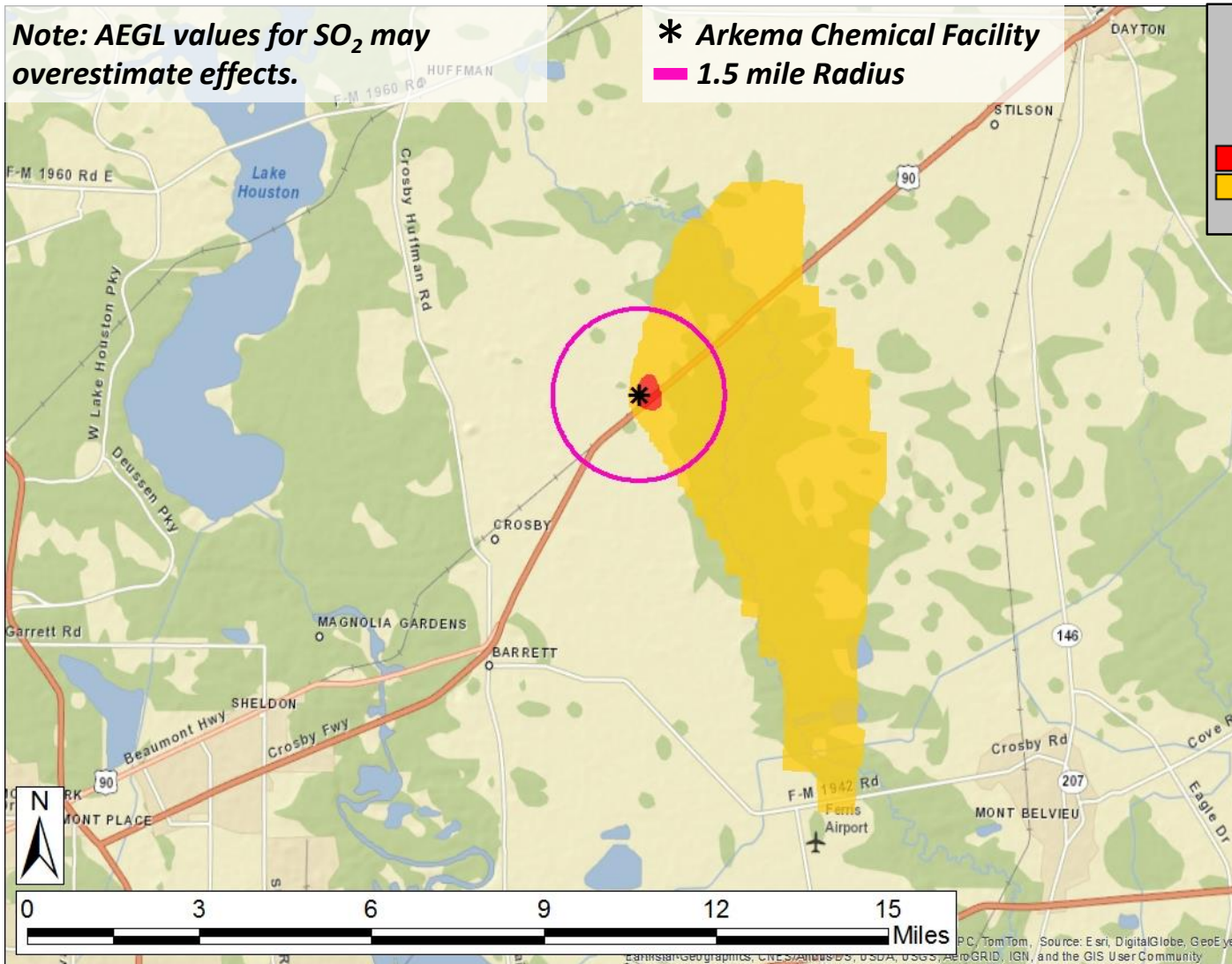
Dissemination: Release over 2 hours

Weather: 3 km NAM

Model: HPAC 6.4

Static Population Estimates:

LandScan 2015





SO₂ (Release Starting @ 03 SEP 9:00 AM CDT) – Update #8

Note: AEGL values for SO₂ may overestimate effects.

* Arkema Chemical Facility
1.5 mile Radius

Sulfur Dioxide(AEGLs)
03-Sep-17 18:00:00Z (4.000 hr)

Mean Area

Value

AEGL-3 Death Possible	3.0
AEGL-2 Injury Possible	2.0
AEGL-1 not displayed	

FACTS

Crosby, Texas

Location: 29.9491° N/ 95.0211° W

Event Time: 9:00 AM CDT, 03SEP2017

Type: Sulfur Dioxide

Amount: 32,000 lb (16,000 lbs/hr)

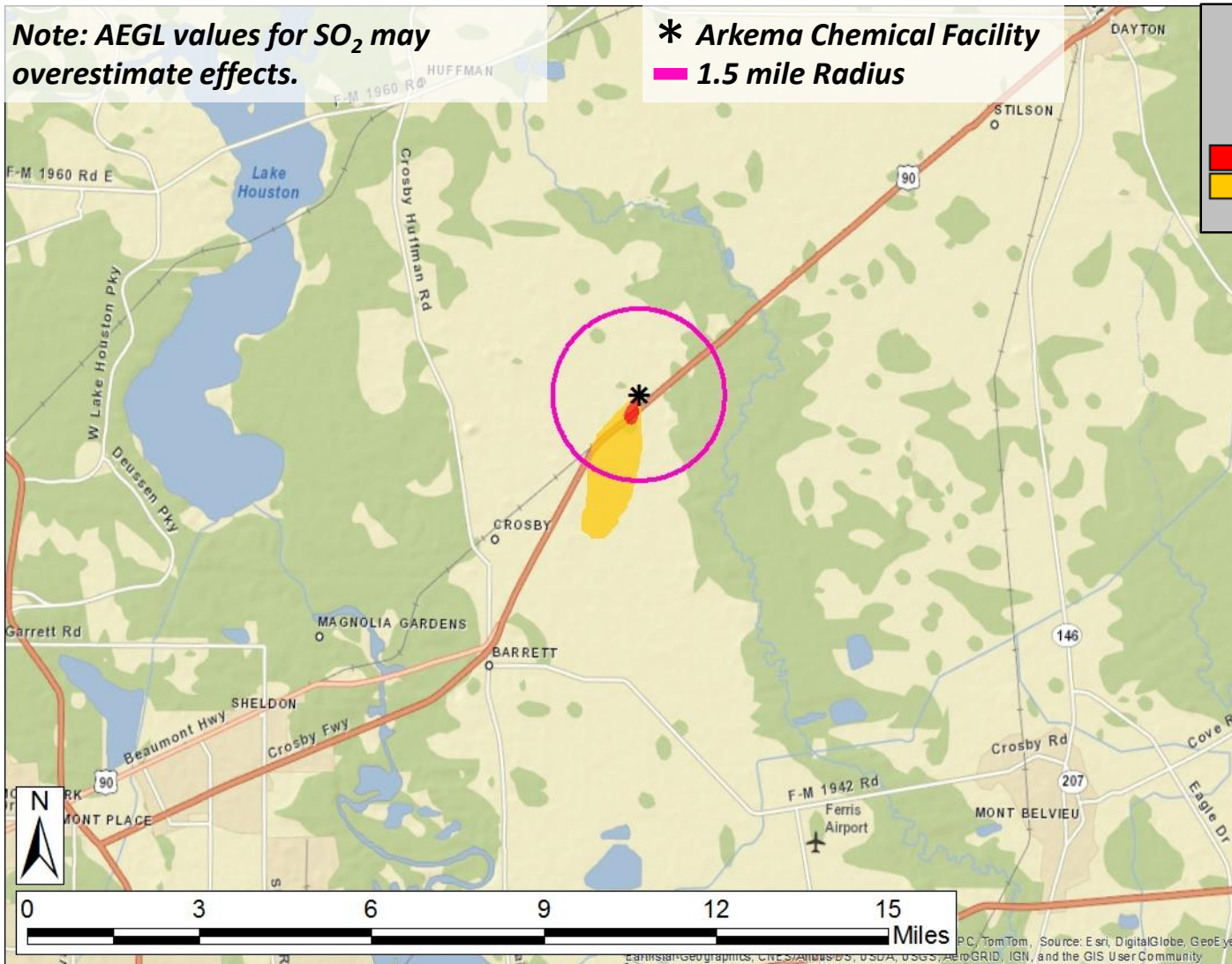
Dissemination: Release over 2 hours

Weather: 3 km NAM

Model: HPAC 6.4

Static Population Estimates:

LandScan 2015



Source: Esri, DigitalGlobe, GeoEye, AeroGRID, IGN, and the GIS User Community



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SO₂ (Release Starting @ 03 SEP 3:00 PM CDT) – Update #8

Note: AEGL values for SO₂ may overestimate effects.

* Arkema Chemical Facility
1.5 mile Radius

Sulfur Dioxide(AEGLs)
04-Sep-17 00:00:00Z (4.000 hr)

Mean Area

	Value
AEGL-3 Death Possible	3.0
AEGL-2 Injury Possible	2.0
AEGL-1 not displayed	

FACTS

Crosby, Texas

Location: 29.9491° N/ 95.0211° W

Event Time: 3:00 PM CDT, 03SEP2017

Type: Sulfur Dioxide

Amount: 32,000 lb (16,000 lbs/hr)

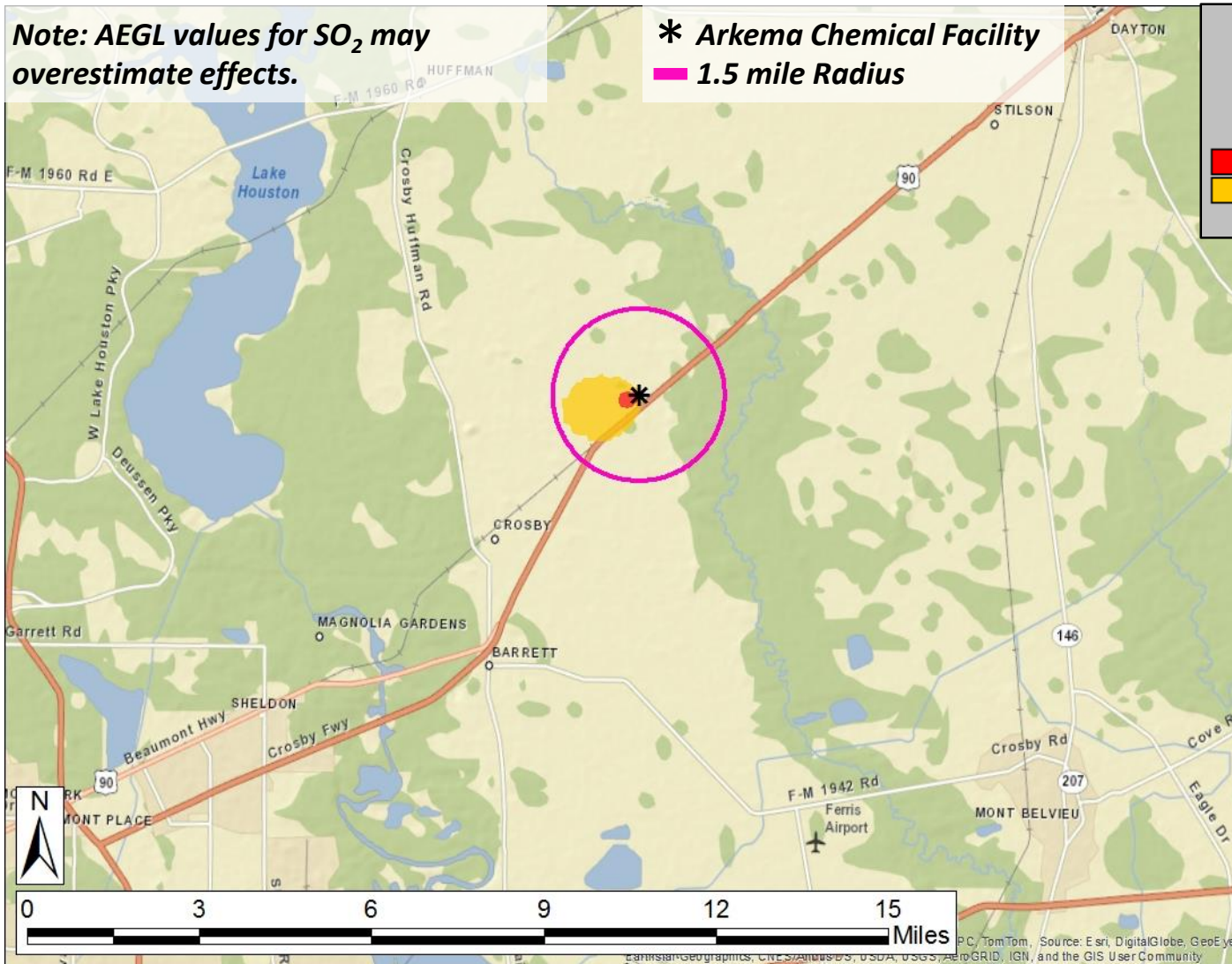
Dissemination: Release over 2 hours

Weather: 3 km NAM

Model: HPAC 6.4

Static Population Estimates:

LandScan 2015



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNR/Siatic Images, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Acute Exposure Guideline Levels (AEGL)

Value	Description
AEGL-3	Death Possible - the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.
AEGL-2	Injury Possible - the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
AEGL-1 (May not be displayed or defined)	Threshold - the airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
10% AEGL-2 Possible or 10% AEGL-1 Possible	90% confidence level that exceeding AEGL-2 or AEGL-1 is possible. If black , this contour accounts for both atmospheric effects and weather uncertainty. If blue , this contour accounts for only atmospheric effects.

AEGLs represent threshold exposure limits for the general public and are applicable to emergency exposure periods ranging from 10 minutes to 8 hours. It is believed that the recommended exposure levels are applicable to the general population including infants and children, and other individuals who may be susceptible.

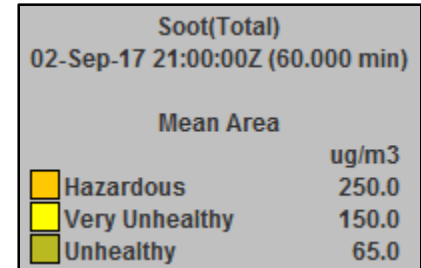
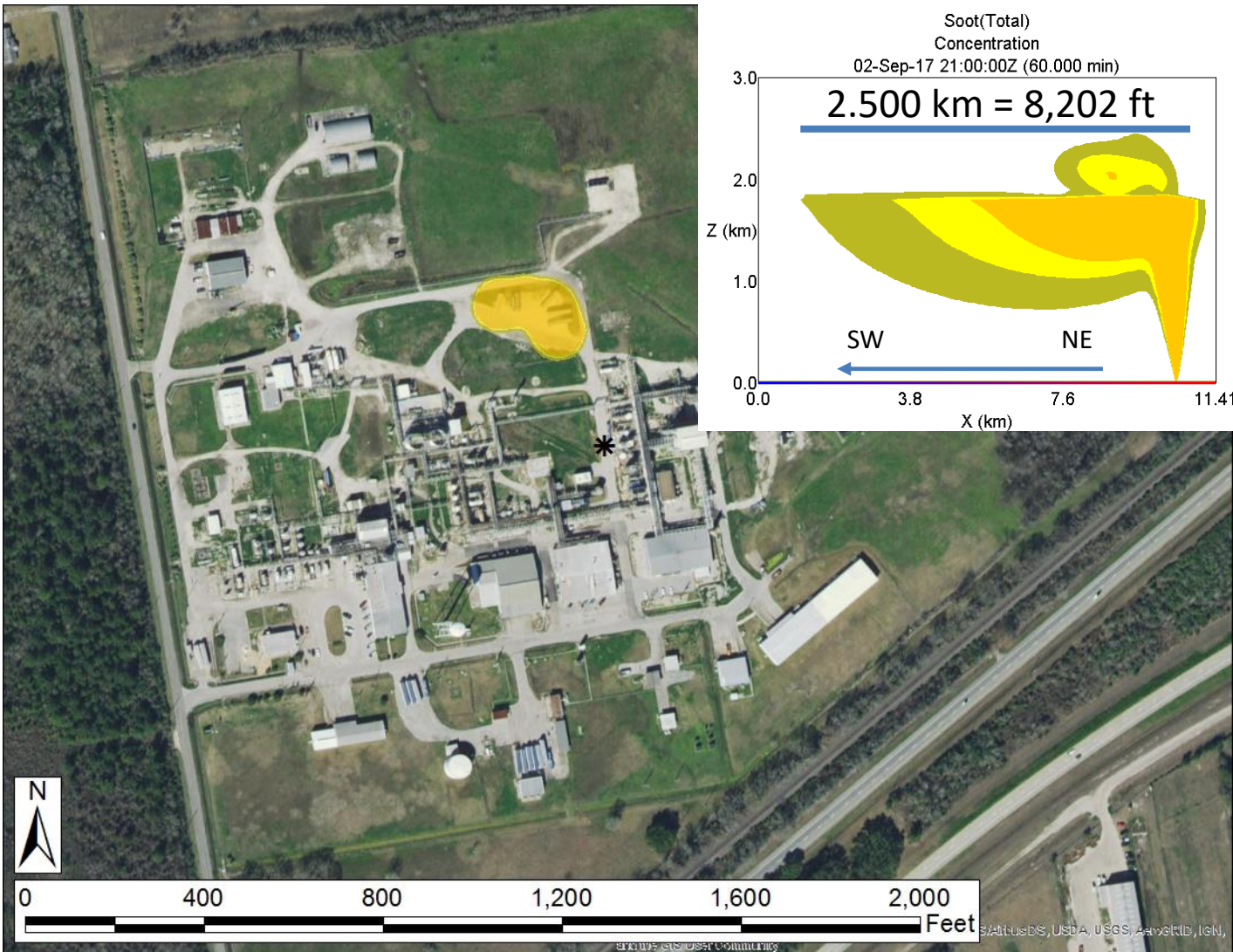
FINAL AEGLs – may be used on a permanent basis by all federal, state and local agencies, and private organizations.

INTERIM AEGLs – represents the best efforts of the AEGL Committee to establish exposure limits, and the values are available for use as deemed appropriate on an interim basis by federal and state regulatory agencies and the private sector.

Notes: Casualty numerical figures are based upon a population database (LandScan). LandScan is based on the 2010 census for the U.S. (other nations vary), overhead imagery, geo-economic, and other observable data and was updated in 2015. The population numbers next to associated hazard levels are the people contained within the entire contour based **upon average day and night** time LandScan 2015 data. **Also available are the average day or night** time LandScan 2012 data (US only). For planning purposes, estimates are assumed to be accurate within +10/-5%. Validation testing indicates agreement within 20% for select examined areas. The population data will not predict major shifts in personnel such as relocations (i.e.: religious pilgrimages, refugees, evacuations), events (i.e.: inaugurations, Olympics), or other population shifts. In such cases the population database needs to be updated to reflect actual conditions.



Soot – Burning Trailer – (Starting @ 02 SEP 3:00 PM CDT) – Update #8



Note: Hazard is from estimated incidental material burning (e.g. tires, trailer, insulation). The combustion products from organic peroxide constitute minimal atmospheric hazards.

FACTS

Crosby, Texas

Location: 29.948086° N/ 95.019951° W

Event Time: 3:00 PM CDT, 02SEP2017

Type: Organic Peroxide

Amount: 6 containers (38,000 lb each)

Dissemination: Release over 1 hour

Weather: 3 km NAM

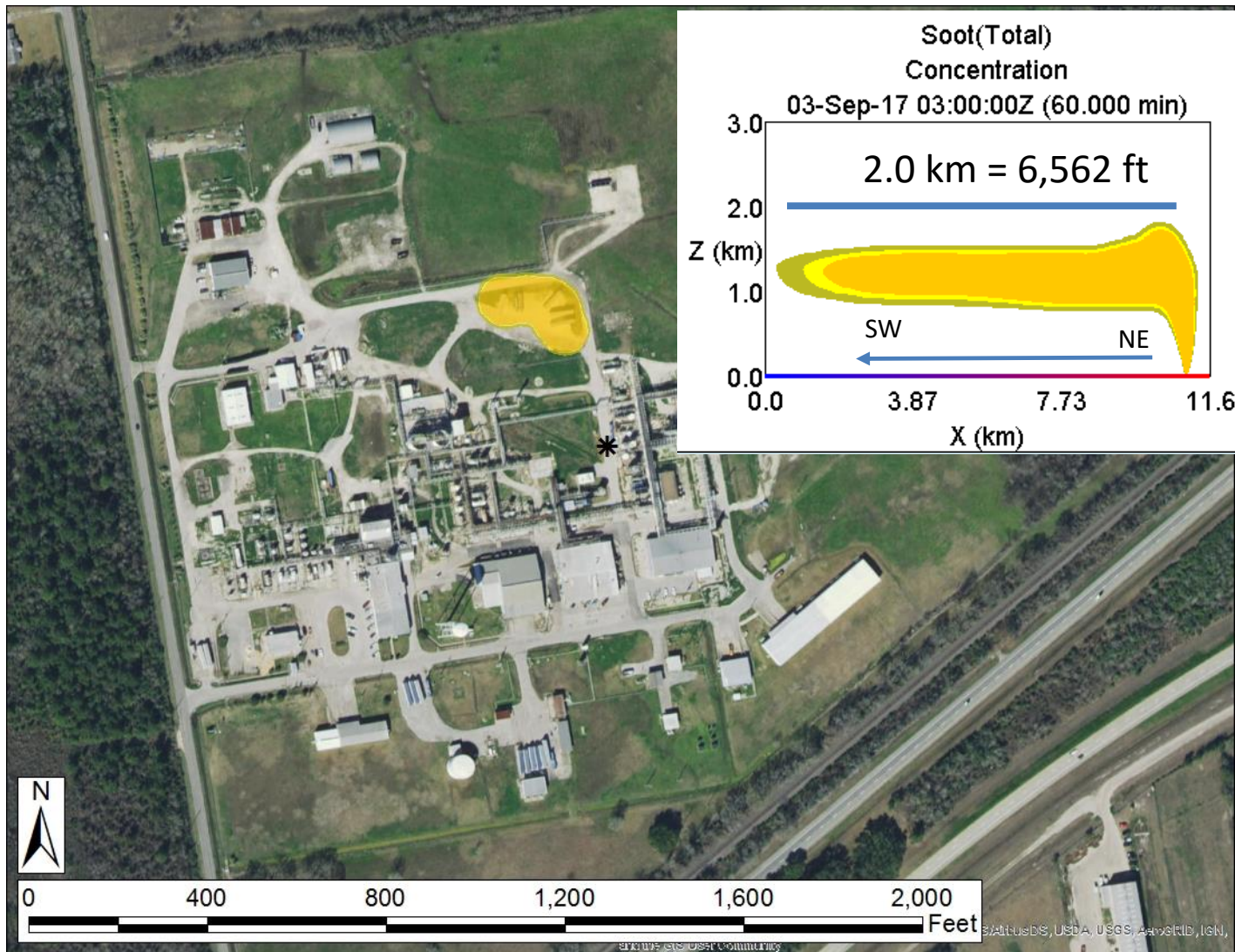
Model: HPAC 6.4

Static Population Estimates:

LandScan 2015



Soot – Burning Trailer – (Starting @ 02 SEP 9:00 PM CDT) – Update #8



Soot(Total) Concentration	
03-Sep-17 03:00:00Z (60.000 min)	
	ug/m3
Hazardous	250.0
Very Unhealthy	150.0
Unhealthy	65.0

Note: Hazard is from estimated incidental material burning (e.g. tires, trailer, insulation). The combustion products from organic peroxide constitute minimal atmospheric hazards.

FACTS

Crosby, Texas

Location: 29.948086° N/ 95.019951° W

Event Time: 9:00 PM CDT, 02SEP2017

Type: Organic Peroxide

Amount: 6 containers (38,000 lb each)

Dissemination: Release over 1 hour

Weather: 3 km NAM

Model: HPAC 6.4

Static Population Estimates:

LandScan 2015

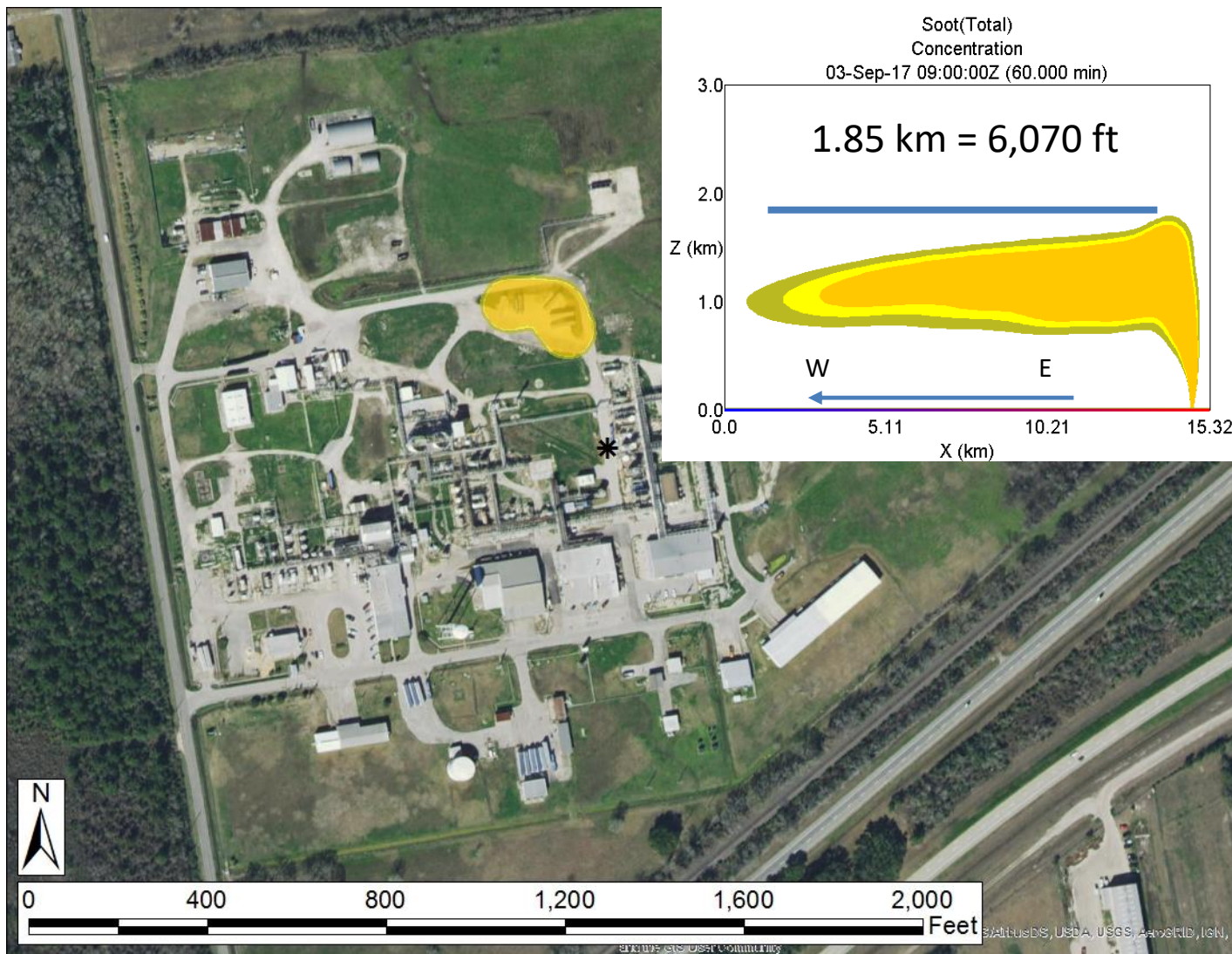
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Soot – Burning Trailer – (Starting @ 03 SEP 3:00 AM CDT) – Update #8



Soot(Total)	
03-Sep-17 09:00:00Z (60.000 min)	
Mean Area	
	ug/m3
Hazardous	250.0
Very Unhealthy	150.0
Unhealthy	65.0

Note: Hazard is from estimated incidental material burning (e.g. tires, trailer, insulation). The combustion products from organic peroxide constitute minimal atmospheric hazards.

FACTS

Crosby, Texas

Location: 29.948086° N/ 95.019951° W

Event Time: 3:00 AM CDT, 03SEP2017

Type: Organic Peroxide

Amount: 6 containers (38,000 lb each)

Dissemination: Release over 1 hour

Weather: 3 km NAM

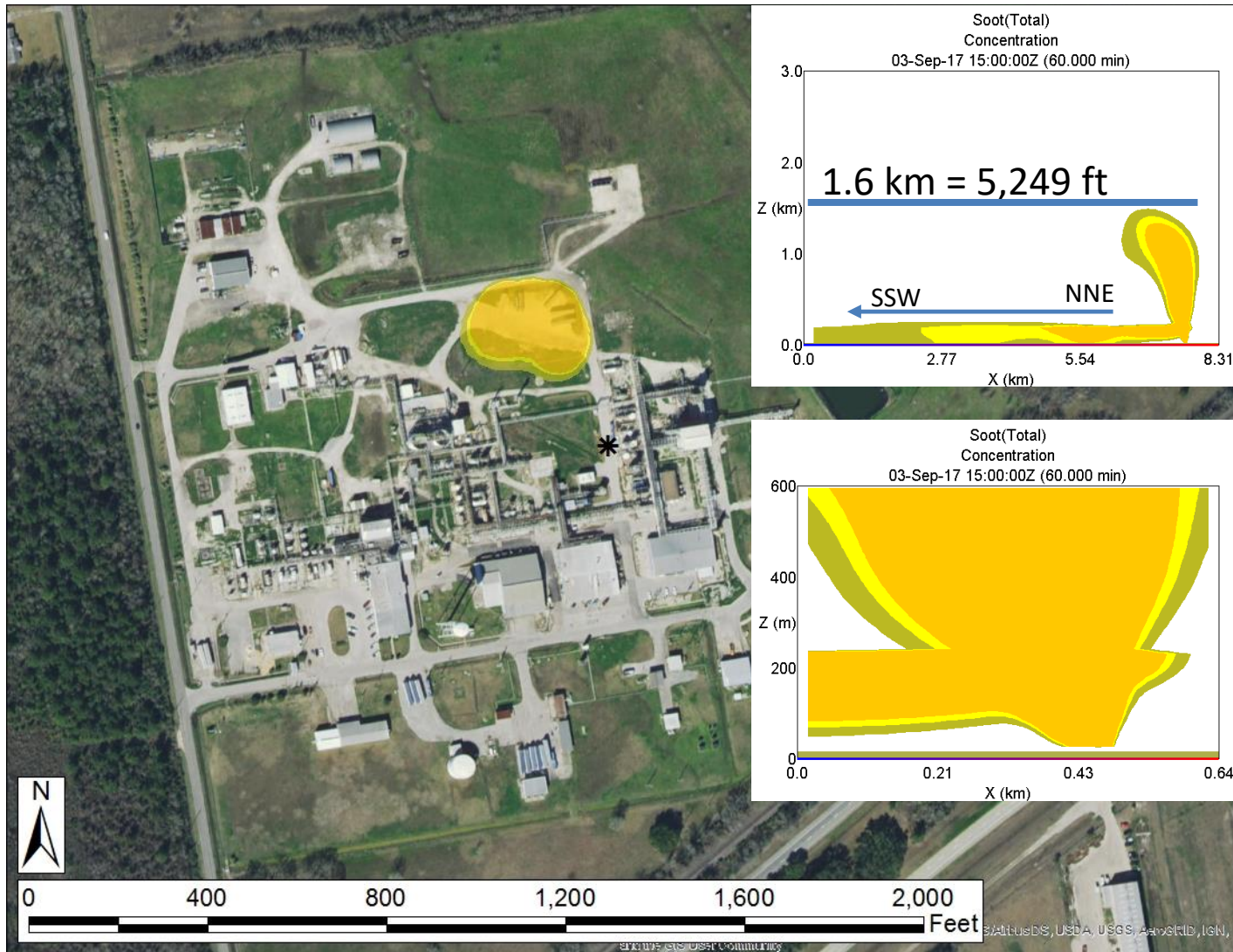
Model: HPAC 6.4

Static Population Estimates:

LandScan 2015



Soot – Burning Trailer – (Starting @ 03 SEP 9:00 AM CDT) – Update #8



Soot(Total) 03-Sep-17 15:00:00Z (60.000 min)	
Mean Area	
	ug/m3
Hazardous	250.0
Very Unhealthy	150.0
Unhealthy	65.0

Note: Hazard is from estimated incidental material burning (e.g. tires, trailer, insulation). The combustion products from organic peroxide constitute minimal atmospheric hazards.

FACTS

Crosby, Texas

Location: 29.948086° N/ 95.019951° W

Event Time: 9:00 AM CDT, 03SEP2017

Type: Organic Peroxide

Amount: 6 containers (38,000 lb each)

Dissemination: Release over 1 hour

Weather: 3 km NAM

Model: HPAC 6.4

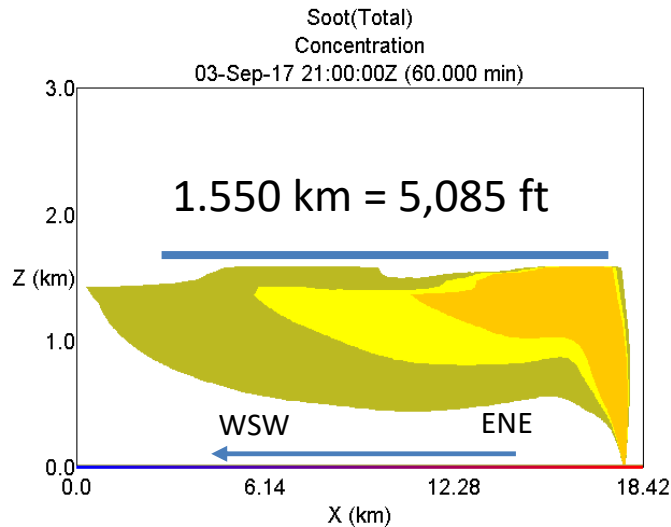
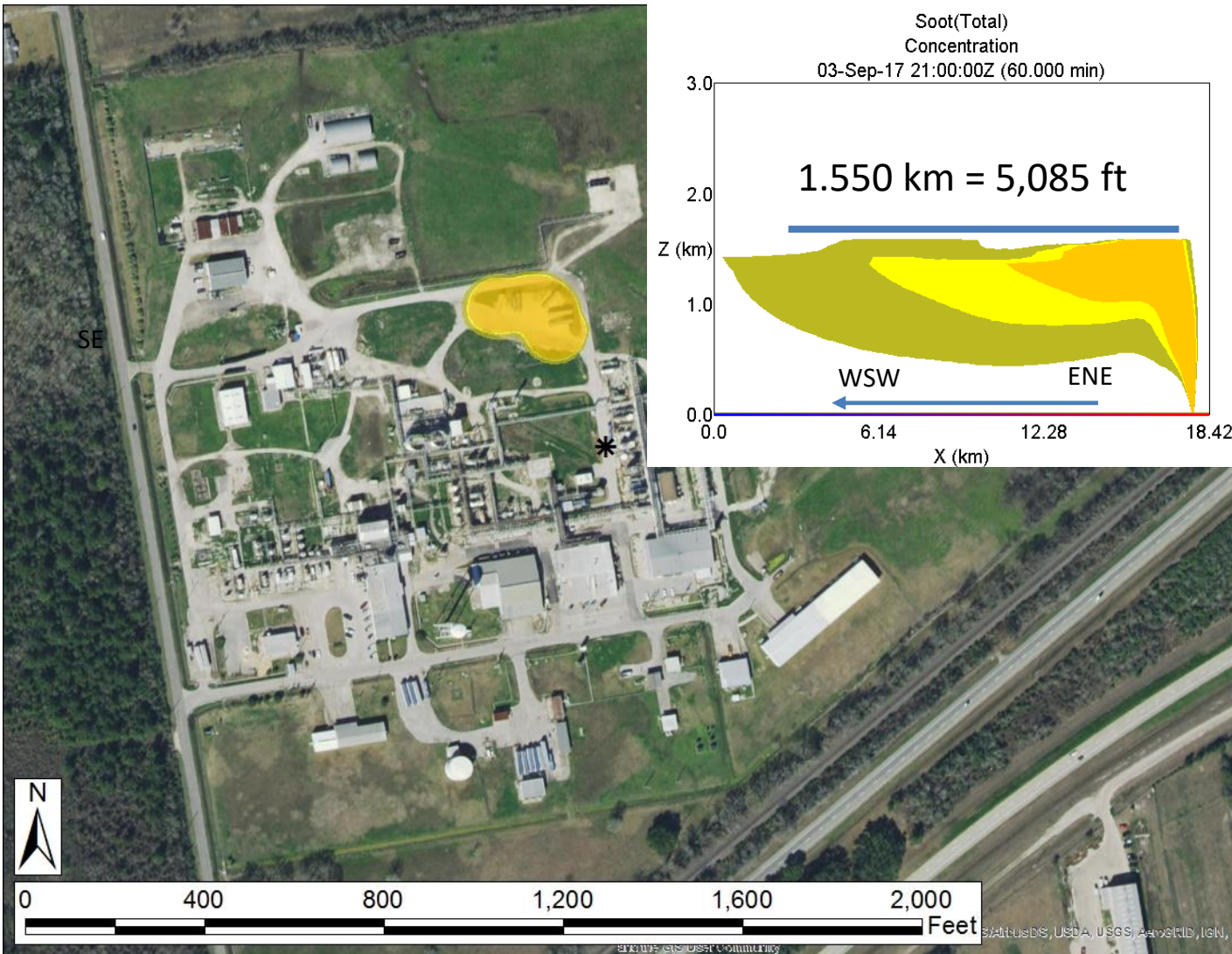
Static Population Estimates:

LandScan 2015



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Soot – Burning Trailer – (Starting @ 03 SEP 3:00 PM CDT) – Update #8



Soot(Total) 03-Sep-17 21:00:00Z (60.000 min)	
Mean Area	
	ug/m3
 Hazardous	250.0
 Very Unhealthy	150.0
 Unhealthy	65.0

Note: Hazard is from estimated incidental material burning (e.g. tires, trailer, insulation). The combustion products from organic peroxide constitute minimal atmospheric hazards.

FACTS

Crosby, Texas

Location: 29.948086° N/ 95.019951° W

Event Time: 3:00 PM CDT, 03SEP2017

Type: Organic Peroxide

Amount: 6 containers (38,000 lb each)

Dissemination: Release over 1 hour

Weather: 3 km NAM

Model: HPAC 6.4

Static Population Estimates:

LandScan 2015



Soot – Concentration

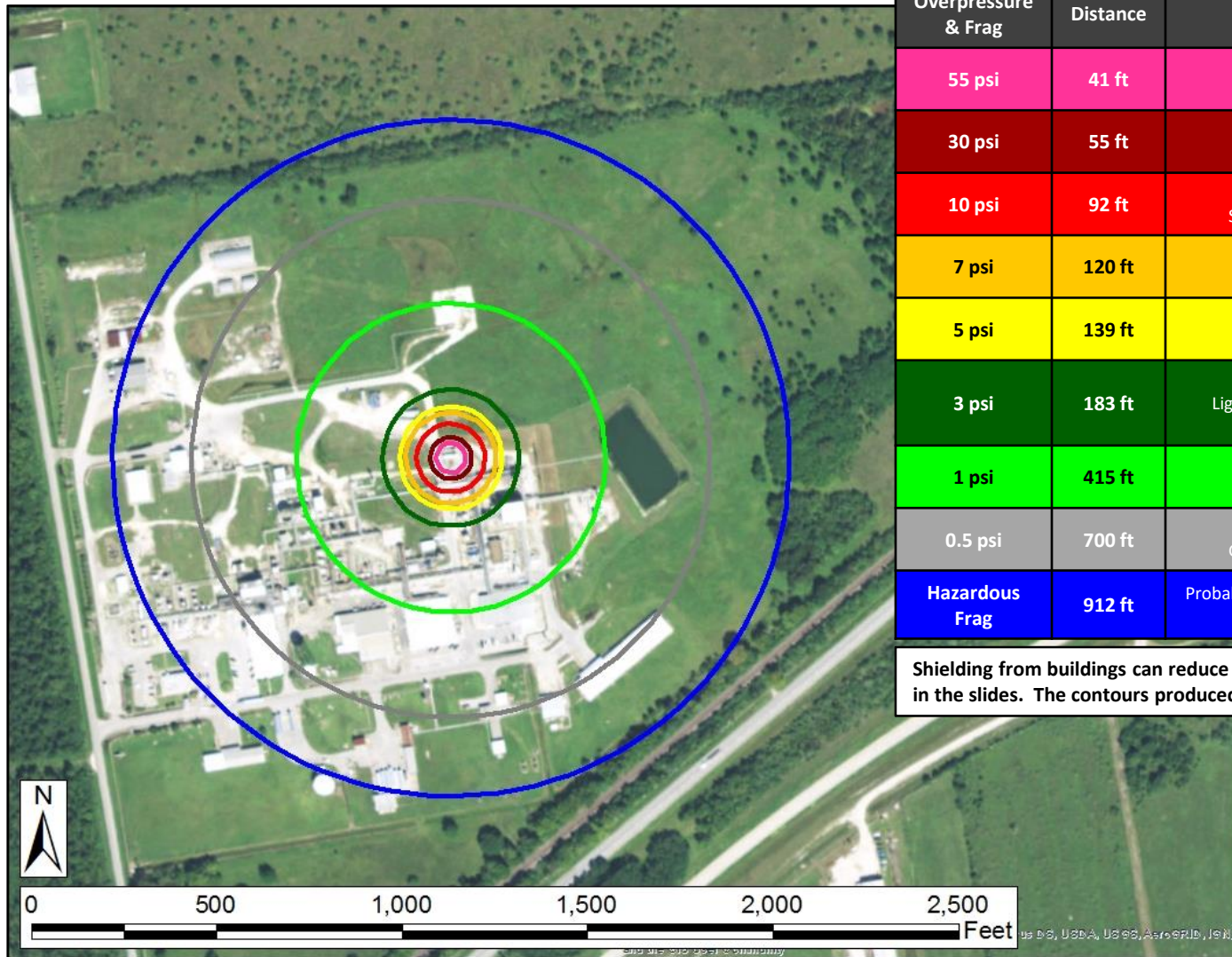


Value	Description
Hazardous	Serious risk of (1) respiratory symptoms in children/adults, (2) aggravation of heart or lung disease, and (3) premature mortality in persons with cardiopulmonary disease and the elderly.
Very Unhealthy	Significant increase of (1) respiratory symptoms in children/adults, (2) aggravation of heart or lung disease, and (3) premature mortality in persons with cardiopulmonary disease and the elderly.
Unhealthy	Increased (1) respiratory symptoms in children/adults, (2) aggravation of heart or lung disease, and (3) premature mortality in persons with cardiopulmonary disease and the elderly.

Cumulative dosage values based on exposure to 2.5um particulate matter. Concentration values and descriptions taken from Pollutant-Specific Sub-indices and Health Effects Statements and Cautionary Statements for Guidance on the Air Quality Index tables, in *Guidelines for Reporting of Daily Air Quality – Air Quality Index (AQI)*, USEPA, EPA-454/B-06-001, May 2006.



Human Injury & Structural Damage Contours – Isobutylene BLEVE



Overpressure & Frag	Distance	Human Injury/Structural Damage (details on following slides)
55 psi	41 ft	100% fatalities Complete structure blowout
30 psi	55 ft	Near 100% fatalities Destruction of primary structural components
10 psi	92 ft	High fatality rate Severe damage to primary structural components
7 psi	120 ft	Widespread fatalities, 50% eardrum rupture Damage to primary structural components
5 psi	139 ft	Universal injuries Severe damage to light structures
3 psi	183 ft	Serious injuries common Light damage to primary structural components, light structures damaged
1 psi	415 ft	Light injuries occur Non-structural component severe damage.
0.5 psi	700 ft	Temporary eardrum damage Glass breaks, non-structural components damage
Hazardous Frag	912 ft	Probability of being struck in the open by primary/hazardous fragmentation is less than 1%.

Shielding from buildings can reduce the hazard-to-effect contour distances shown in the slides. The contours produced are representative of open terrain effects.

FACTS

Crosby, Texas

Location:

29.949° N / 95.022° W

Amount: 780.4 lb TNT-equivalent

Model: BOOM (JIEDDO)



Human Injury & Structural Damage Contours

	Personnel	Glass	Wood	Metal	Concrete Block	Reinforced Concrete
55 psi	100% fatalities	Complete destruction	Complete destruction	Complete destruction	Complete destruction	Complete destruction
30 psi	99% lung damage, fatalities approach 100%	Shatters, severe frame failure	Collapse, complete destruction	Siding and interior destroyed	Collapse	Complete destruction
10 psi	>50% eardrum rupture, high fatality rate	Shatters, severe frame failure	Collapse, complete destruction	Siding and interior destroyed	Collapse	Concrete shatters, steel remains
7 psi	50% eardrum rupture, widespread fatalities	Shatters, severe frame failure	Collapse, complete destruction	Siding and interior destroyed	Collapse	Severe spalling, walls displaced
5 psi	Chance eardrum rupture, injuries are universal	Shatters, severe frame failure	Collapse, complete destruction	Siding and interior destroyed	Severe damage	Moderate cracking
3 psi	Threshold eardrum rupture, serious injuries common	Shatters, severe frame failure	50% collapse	Siding and interior destroyed	Severe damage	Moderate cracking
1 psi	Temporary eardrum damage, light injuries occur	Shatters	Studs, sheathing cracked	Severe buckling, some panels torn off	Severe damage	N/A
0.5 psi	Temporary eardrum damage	Shatters	Rafters cracked	Moderate buckling, joints separated	N/A	N/A

Hazardous Frag (Robust)	Maximum Frag (Robust)
The distance to which primary fragment concentration is no more than one per 600 ft ² area. Equates to 1 percent probability of a person to be struck by a hazardous fragment while standing in the open.	The distance to which munitions primary and secondary fragments from the PES are not expected to travel beyond the ES (explosive site) posing a threat to personnel exposed in the open in the horizontal plane.

- Shielding from buildings can reduce the hazard-to-effect contour distances shown in the slides. The contours produced are representative of open terrain effects.
- Fragmentation calculations assume a cased projectile. Irregular IED construction may vary from provided estimates.